FINAL DRAFT

COMPILATION OF THE RESEARCH PERFORMED THROUGH THE DEPARTMENT OF DEFENSE LEGACY RESOURCE MANAGEMENT PROGRAM

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ATLANTIC WHITE-CEDAR ECOSYSTEM RESTORATION ON ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE AND UNITED STATES AIR FORCE DARE COUNTY RANGE

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Abstract--Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.) was historically a major component of the mid-Atlantic forested wetland ecosystem. Nearly 10,000 acres of Atlantic white-cedar were clearcut on the Dare County mainland of North Carolina prior to the establishment of Alligator River National Wildlife Refuge and U.S. Air Force Dare County Range. In 1992, a cooperative project involving Alligator River National Wildlife Refuge, U.S. Air Force Dare County Range, North Carolina Division of Forest Resources and North Carolina State University was initiated for the purpose of performing large-scale restoration of Atlantic white-cedar in clearcut areas. The project was funded through the Department of Defense Legacy Resource Management Program. Intensive regeneration surveys on 3,000 acres of clearcuts on Refuge and Range lands were initiated in 1995 to determine the status of natural regeneration. Preliminary results indicate that adequate natural regeneration exists in most of the cut-over tracts sampled to date. However, data analyses and field observations suggest that the occurrence and establishment of Atlantic white-cedar are extremely variable and are directly correlated with soil disturbance, shrub competition, and hydrologic condition. Immediate plans to restore stands characterized by adequate Atlantic white-cedar regeneration and dense competing vegetation consist of chemically releasing the struggling Atlantic white-cedar seedlings and saplings from competing hardwood species.

INTRODUCTION

Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.), known locally as juniper, was once a major component of the forested wetland ecosystem throughout the Dare County peninsula. Intense logging, wildfire and drainage coupled with the lack of proper forest management have resulted in a near 90 percent decrease in the coverage of Atlantic white-cedar in North and South Carolina from that which existed before European settlement (Smith 1995). During WWI (1916-19), all of the available Atlantic white-cedar was harvested by numerous operators on 159,997 acres (64,750 ha) of the Alligator River region. Throughout this period of intense harvesting, no attempts were made to encourage natural regeneration, and harvest methods indicate little concern for future timber production. The harvest of Atlantic white-cedar and associated species, prior to 1920, had a significant effect on the vegetation patterns that exist today. The timber practices determined regeneration densities and species composition. However, the hydrology of the organic substrate was apparently not substantially altered, for the use of oxen and, later narrow gauge rails to move timber did not necessitate elaborate permanent road construction.

Since the mid-1970s, Atlantic white-cedar has been the most valuable timber species in the Alligator river region. An elaborate network of roads, canals and ditches were constructed to provide direct access to the pure, dense stands (Laderman 1989). Recent large-scale harvesting of Atlantic white-cedar began on the Alligator River National Wildlife Refuge and Dare County Range in 1975, prior to the establishment of the Refuge in 1984. The U.S. Fish and Wildlife Service (USFWS) received a large portion of the land through a donation from The Nature Conservancy who received the land through a temporary donation from Prudential. However, the timber rights, which did not expire until 1996, were owned by Atlantic Forest Products. The timber rights were sold to Atlantic Forest Products by First Colony Farms prior to ownership by Prudential. Most of the Atlantic white-cedar stands on the Refuge had already been harvested by the late 1980's or early 1990's. Very little logging took place on the Refuge during the final years of the outstanding timber deeds. The Range, established in 1964, was in a similar situation. Timber rights to Range property were not purchased by the Department of Defense until 1981. These recent logging operations left both landowners with approximately 10,000 acres of Atlantic white-cedar clearcuts and scattered disjunct remnants of Atlantic white-cedar stands.

Poor logging practices, lack of post-harvest forest management, and hydrologic alterations have collectively resulted in poor Atlantic white-cedar regeneration in some areas. One of the major objectives in the overall management of the Refuge is the preservation of unique habitats. Therefore, restoration of Atlantic white-cedar habitat is a priority in Refuge management practices.

Regeneration surveys to determine the status of natural regeneration in nearly 30 cut-over stands on the Refuge were conducted in 1986-88. Surveys results revealed that adequate natural regeneration was very patchy. Follow-up surveys of the same areas, conducted in 1991-92, confirmed this trend but also revealed several other facts of interest: regeneration continued to occur in clearcut areas where it was found to be occurring in 1986-88; and those clearcuts in which no regeneration was occurring in 1986-88 were completely captured by broadleaf trees and shrubs.

Hydrologic conditions throughout the Dare County peninsula have been significantly altered over the past 50 years resulting in the drainage or flooding of forested and previously forested wetlands. Prior to the recent logging operations, approximately 5,000 acres of forested wetlands were drained, cleared and converted to agricultural land. Aside from the deliberate destruction of forested wetlands, the construction of access roads has indirectly resulted in significant changes in the hydrologic regime. Access roads were constructed using material excavated from adjacent borrow canals. At the time of construction of the more recent roads, the U.S. Army Corps of Engineers prohibited the alteration of the hydrology of an area; therefore, they did not allow connecting the man-made canals to an existing natural drain. By not providing an outlet for the canals, ground and surface water which once followed natural drainage contours became impounded by the roads. The actual impact of a road or canal on a given stand depended on the orientation of the road and on which side of the road the canal was dug. The roads essentially serve as dikes which restrict the flow of water into or out of a stand. The overall effects of the road and canal system have been steady declines in forest health and atypical shifts in species composition of most forested ecosystems. It is our intent to restore historic drainage patterns as best we can in order to again perpetuate Atlantic white-cedar and other native ecosystems.

In 1992 the US Air Force Dale County Range received special funding through the Department of Defense Legacy Resource Management Program to perform large-scale wetland forest restoration, specifically Atlantic white-cedar restoration. The Range soon formed a cooperative partnership with the USFWS at the Refuge, North Carolina Division of Forest Resources (NCDFR) and North Carolina State University. A steering committee consisting of representatives from all of the above agencies was established for the primary purpose of combining knowledge and expertise in the field of wetland restoration and to ensure that only those projects directly related to the establishment of Atlantic white-cedar were provided funding. Several of the goals set forth by the committee are as follows: 1) inventory cut-over Atlantic white-cedar stands using Differential Global Positioning Systems (DGPS) to determine status of natural regeneration; 2) establish a Geographic Information System (GIS); 3) promote and enhance natural regeneration; 4) develop seed and seedling sources; 5) develop and implement methods of artificial regeneration; and 6) establish water control and management to restore hydrology.

For the purpose of this project, restoration efforts will be concentrated on 3,000 acres of nearly contiguous cut-over Atlantic white-cedar stands located on the Refuge and Range property.

METHODS

Inventory Cut Over Stands

Plans to perform regeneration surveys on the 3,000 acres of Atlantic white-cedar clearcuts were initiated in 1994. The plans originally called for bids from private contractors to conduct surveys and provide the desired final products. Bids received from nearly all prospective contractors greatly exceeded budget allocations. The committee then decided to hire temporary USFWS employees to conduct the surveys and provide oversight for all field operations. The purpose of the survey that began during the summer of 1995 was to determine the success or failure of natural Atlantic white-cedar regeneration in clearcuts and to identify critical limiting factors that might affect the germination and long-term survival of the species.

The survey is being performed on an individual-stand basis. Stand delineation is determined by the intersecting road network. Four tenths of 1 percent of the entire project area will be inventoried using systematic sampling techniques. Two fixed-area circular plots that are 1/500 of an acre in size are sampled per acre. Plots are installed 104 feet apart along transects that are 208 feet apart. As a rule, transects are laid out perpendicular to the access roads. Field crews must suffer through vicious insects, even more vicious catbrier and extremely unstable ground to blaze numerous trails through the nearly impenetrable vegetation and mark plot centers. Once the plots are laid out along a transect an additional set of crew members locate the plots and collect the data. A total of 400 permanent plots will be established in stands approximately 20 acres in size or in 20 acre blocks within larger stands.

Actual data collected in the field consists of: 1) the number of stems of Atlantic white-cedar and other economically and ecologically significant species such as black gum (Nyssa sylvatica), bald cypress (Taxodium distichum), pond pine (Pinus serotina) and loblolly pine (Pinus taeda) in several height classes (< 1 foot, 1-3 feet, 3-5 feet, 5-7 feet and > 7 feet); 2) the estimated percent cover of the top three plant competitors on the plot; 3) the depth of standing water; 4) the depth of peat layer: and 5) a brief description of the plot and surrounding area.

All data are recorded with hand-held data loggers that are an integral component of a DGPS. A digital data sheet referred to as a data dictionary is created and stored within the data logger. The data dictionary ensures that all required data are collected and recorded in the proper format. As a backup, data are also recorded on data sheets. Generally, at the end of each work week, all of the stored data files are downloaded from the data logger to a PC where they are processed further. In addition to the descriptive data collected at each plot, the geographic location of the plot center is generated by a DGPS and stored in the data logger. Unfortunately, raw DGPS positions generated in the field are usually very inaccurate as a result of inherent errors in satellite orbits and clocks. Due to these inherent inaccuracies, raw coordinate data must be corrected through a process called differential correction, which utilizes data generated by a DGPS base station to more accurately calculate the location of a given position. A DGPS base station consists of a DGPS receiver located at a known position with a clear view of the sky that records data from the same satellites and at the same time as the rover unit (Trimble 1996). Since a base station knows its precise location, it is able to calculate the amount of error transmitted in raw satellite data. This error data is then utilized in a post-processing program to recalculate more precise locations. Through differential correction, DGPS units utilized are capable of achieving sub-meter accuracy and routinely achieve 3-meter accuracy.

Once all of the geographic positions have been differentially corrected, the data files for a given stand are combined, downloaded into a spread sheet and statistically analyzed. Stand averages, ranges and variations are calculated for the following variables: number of stems per acre of all species in all height classes, as well as for Atlantic white-cedar stems over 5 feet tall; percent cover of the top three competitors; water depth; and peat depth. Both raw field data and calculated stand statistics are then incorporated into a GIS

Geographic Information System

A GIS has been developed for the Dare County Peninsula that consists of the following base layers: landmass, roads, lakes, creeks, canals and V-ditches. In the near future, all of the data generated by the regeneration survey will also be incorporated into the GIS. Once integrated into the GIS, the raw database will display the geographic location of individual plots and transects and can be manipulated to display geographic ranges of different levels of Atlantic white-cedar regeneration, percent competition, stocking of other tree species, water depth and peat depth.

The statistical database for each stand will be linked to the entire stand and can be used to display data such as number of stems per acre of each species, average percent coverage of the top three competitors, and much more. More detailed thematic maps can also be generated that display Atlantic white-cedar stands differently based on the following stocking ranges: <850, 850-1000, and >1000 stems per acre. The actual outline of the cut-over areas will be digitized from 1996 digital orthographically corrected aerial photography. Future plans not only include the use of digital aerial photography for the mapping of vegetation but also the use of satellite imagery.

Promote and Enhance Natural Regeneration

Although natural regeneration of Atlantic white-cedar is occurring in all of the stands inventoried, stocking levels vary significantly between and within stands. For the purpose of this project, a stand is considered to be adequately stocked if it contains an average of 850 Atlantic white-cedar trees per acre, greater than 5 feet in height. Due to the ingrowth of new germinates and accelerated mortality rates of seedlings and smaller saplings, more emphasis is placed on the stocking of trees in the larger height classes that may have a better chance of survival.

Successful regeneration of Atlantic white-cedar has been hindered due to the shade intolerance of the species. Atlantic white-cedar seedlings growing under a closed canopy are believed to survive no longer than three years (Little 1950). Nearly all Atlantic white-cedar cut-over areas on the Refuge and the Range are characterized by an extremely dense layer of hardwood shrubs, vines and trees that compete with Atlantic white-cedar for light and nutrients.

In order to promote seed germination and ensure the survival of Atlantic white-cedar seedlings and saplings, the competing hardwood vegetation must be controlled. Plans to release Atlantic white-cedar from competition from undesirable woody vegetation consist of herbicide application. The brand Arsenal (Isopropylamine salt of Imazapyr) will be applied aerially at a rate of 16-20 ounces per acre. Sites chemically treated with approved tank mixes, applied at a rate of 16 to 23 ounces per acre, are guaranteed to be at least 80 percent free to grow for two years following application. The release from competing vegetation will increase the amount of sunlight reaching the forest floor, which will enhance seed germination and seedling survival. The duration of the free-to-grow period will give Atlantic white-cedar trees in all stages of development at least a 2-year head start toward establishing themselves and dominating the stand. This method must be performed in conjunction with hydrologic restoration to improve conditions for seed germination and seedling survival. Under the right conditions, existing seed sources will germinate in response to the increase in light, and Atlantic white-cedar seedlings and saplings will be able to out-compete encroaching hardwood vegetation.

Stands that contain an average of 850 Atlantic white-cedar trees per acre > 5 feet tall will be a higher priority for restoration due to the greater probability of success. Stands that contain fewer trees will be a lower priority since they may require more costly and labor-intensive treatments such as site preparation and planting.

Develop Seed and Seedling Source

As the efforts to regenerate and restore Atlantic white-cedar increase, so will the demand for Atlantic white-cedar seedlings. Extensive research has been conducted to test seed quantity, seed quality, environmental parameters needed for germination, nursery conditions, and seedling size. Although most of the seedling production techniques are not yet perfected, nurseries have been successful in producing large quantities of Atlantic white-cedar seedlings. Aside from the cost, the primary limitation of consistently producing large quantities of seedlings is availability and quality of seed. Atlantic white-cedar cone collection is an extremely labor-intensive operation. The process usually involves the felling of dominant to co-dominant trees in order to reach the tree crown and harvest cones. Research has shown that seed collected from smaller, immature trees is just as viable as seed collected from mature trees (Bonner 1996). However, mature trees usually produce larger, more dense crops of cones which make collection more productive. Cones are also collected from smaller trees that are growing along the roadside or in a plantation-type stand. Atlantic white-cedar cone production is cyclical; therefore, the availability of cones fluctuates from year to year. Flooding can cause additional stress to trees resulting in poor cone production.

At the Refuge, we dedicate a minimum of one month per year to Atlantic white-cedar cone collection. Cones collected are sent to the NCDFR tree nursery, where the seeds are extracted, cleaned, tested for viability and either planted the following spring to meet our seedling demands or put in cold storage for future needs. Additional research has been performed to develop methods of producing Atlantic white-cedar trees from cuttings. Weyerhaeuser Company has been successfully producing and selling rooted cuttings from mature trees for several years; however, the cost of the trees is significantly higher than the price of seedlings. If the demand for seedlings continues to increase, and easier methods for collecting seed are not developed, cuttings may be the only practical means of producing Atlantic white-cedar nursery stock.

Develop and Implement Methods of Artificial Regeneration

Artificial regeneration of Atlantic white-cedar on the Refuge and Range has been performed on a limited basis. Nearly 100 acres have been hand planted, including a 5-acre genetic test plot, a 5-acre Atlantic white-cedar cone production site and approximately 90 acres of recent clearcuts on the Range. In most cases, the cut-over areas were planted within a year after harvest; therefore, accessibility and site preparation were not issues. Conducting large-scale artificial regeneration in clearcuts that are 5 to 10 years old is much more problematic due to the dense vegetation. It would be nearly impossible for a planting crew to efficiently maneuver through the brush while maintaining proper spacing of the seedlings. Additionally, any seedlings planted under the dense shrub layer would soon die due to the competition for nutrients and light.

In 1996, a study to test various methods of site preparation for planting Atlantic white-cedar was attempted. The study was developed to determine the effectiveness of herbicide, mowing, drum chopping, and burning plus the combination of burning and each of the other three methods. Due to the extremely wet conditions, the only type of preparation successfully performed was mowing which proved to be too expensive and impractical for large-scale site preparation. Due to the failure of the other three methods, herbicide application was not attempted and no Atlantic white-cedar seedlings were planted. Plots that were mowed displayed vigorous growth of undesirable trees, shrubs, grasses, and ferns that completely dominated the site within two growing seasons. This method, unless followed up with chemical control, would provide little benefit to seedling growth. Artificial means of regenerating Atlantic white-cedar in cut-over stands on the Refuge will be performed only in situations where methods to promote or enhance natural regeneration have failed. As it now stands, there are more naturally regenerating stands in need of restoration than we can afford to manage in the near future. Artificially regenerating Atlantic white-cedar is not only more costly but also has a much lower probability of success than restoring stands in which natural regeneration is occurring. Regardless of the method of site preparation, the planted seedling will most likely require some type of silvicultural treatment in order to keep them relatively free to grow.

Hydrologic restoration

Efforts to restore the hydrology on the Refuge were first initiated in 1989 with the installation of water-control structures in the outlets of several major canals. In 1992, Legacy funding provided means to expand our restoration efforts and provide water-control capabilities in areas having a direct impact on Atlantic white-cedar regeneration. A significant number of structures have been installed that provide water control for thousands of acres. However, hydrologic restoration has not yet been achieved in all of the 3,000-acre study area. Several structures are to be installed in canals directly adjacent to the study area, while the remaining structures that still require permitting and purchasing will most likely be installed in the near future. It is essential to achieve some level of hydrologic restoration before any regeneration efforts can be attempted.
In addition to establishing water control, a hydrology study is planned to monitor water quality and flow throughout the 3,000-acre study area. Long-term monitoring will generate baseline data for determining current conditions, management needs, and the effect of restoration efforts.

RESULTS AND DISCUSSION

Preliminary results of stand inventories reveal that natural regeneration of Atlantic white-cedar is occurring in nearly all stands. However, stocking levels between and within stands are extremely variable. Variations in stocking between stands appear to be directly associated with hydrology, site disturbance, and density of competing vegetation. Although it was not a variable in this inventory, the time of year a stand was harvested can also be correlated to the success of natural regeneration (Smith 1995). The variability, or patchiness of regeneration within a stand is most likely a result of micro-topography, site disturbance, and variation in shrub density. It has been suggested that micro-topography is a primary component of Atlantic white-cedar regeneration (Akerman 1923, Little 1950). As a result of drastic soil disturbance in the skid trails, nearly all vegetation growth occurs between the trails, where it tends to be higher and drier. Skid trails within all of the stands are wetter than surrounding areas and are devoid of any soil properties essential for supporting tree growth. Seed stored within the area of skid trails prior to logging was also most likely destroyed by equipment traffic.

Despite some minor variation in species composition between the stands, the one variable which remains constant is the extremely dense shrub layer. In all stands inventoried, the primary cause of failed regeneration is competing hardwood vegetation. Aside from the competition for nutrients, Atlantic white-cedar must also compete for light which is essential for seedling survival and seed germination. Hardwood growth is usually so dense that it creates a nearly closed canopy. In addition to the shrub canopy, the leaf litter deposited by the deciduous species also acts as a barrier to light, thus inhibiting seed germination. Throughout the majority of the stands, the primary hardwood competitors, are fetter bush (Lyonia lucida), laurel or bamboo green briar (Smilax laurifolia), green briar (S. walteri), gallberry (Ilex coriacea), bitter gallberry or inkberry (I. glabra) and waxmyrtle (Myrica cerifera).

Also correlated with the success of Atlantic white-cedar regeneration is the presence of Sphagnum moss (Smith 1995). Sphagnum is the most common substrate on which Atlantic white-cedar seed germination occurs (Little 1950). The presence of Sphagnum also appears to be directly correlated with light availability. Dense carpets of Sphagnum are present only within areas that receive nearly full sunlight, such as skid trails. Unfortunately, these sites often remain too wet for seed germination and seedling survival.

Although regeneration within a stand is patchy or occurs in rows between skid trails, many of the stands were found to contain an average of at least 850 trees per acre in the > 5-foot height class. One stand was determined to be regenerating successfully on its own with little competition and will require no treatment. Most of the other stands, although adequately stocked, will require silvicultural treatment. Plans to alleviate the effects of competing vegetation consist of herbicide application which will be administered in the near future. To date, chemical release from competing vegetation appears to be the only viable means of enhancing natural Atlantic white-cedar regeneration. Long-term monitoring of the effects of the chemical release will be accomplished by resurveying permanent plots that were established in several of the stands.

Development of a complete GIS will be a continuing effort. All ecosystem-related data will eventually be incorporated into a GIS, which will become one of our most valuable tools for managing all aspects of the Refuge and Range.

Although necessary at times, planting Atlantic white-cedar has proved to be so difficult that natural regeneration is preferred in areas where the opportunity exists (Laderman 1989). Planting seedlings or cuttings is more costly and usually requires some type of follow-up treatment to minimize ingrowth of potential competition. The collection of seed for use in nursery production continues to be extremely labor-intensive. Producing Atlantic white-cedar trees from cuttings seems to be a simpler approach; however, the price of cuttings remains significantly higher than seedlings.

As a result of the altered hydrology, some of the stands are flooded for extended periods. Standing water prevents the germination of seeds, induces additional stress, and kills nearly all new germinates. Completing the hydrologic restoration project on the Refuge and Range will take a considerable amount of time. We anticipated having water control throughout the majority of the entire 3,000-acre study area by the end of spring 1998. By installing water-control structures at key locations at the intersections of roads adjacent to cut-over stands, surface and ground water will be able to flow in and out of stands more naturally.

Hydrologic restoration in conjunction with chemical release is essential to the success of natural regeneration of Atlantic white-cedar in most of the inventoried cut-over tracts. With any luck, the inventory of the 3,000 acres will be completed by the end of the 1997 field season. Once the inventory, data analysis, and hydrology restoration are complete, plans to release Atlantic white-cedar regeneration can be implemented. The overall goal of this project is to restore the entire 3,000-acre study area; however, the number of acres restored will be determined by the limited amount of funds available. Due to limited funding, stands with the greatest amount of natural regeneration will be treated first, while the rest of the stands will be prioritized accordingly and treated as additional funding becomes available. The 3,000 acres of Atlantic white-cedar clearcuts sampled during this study is only a fraction of the total clearcut acreage in need of restoration on the Refuge and Range. Therefore, restoration efforts should be incorporated into the overall management of the ecosystem.

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Restoration of an Atlantic White-Cedar Forest Ecosystem at Dare County Air Force Range, North Carolina

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Abstract--In 1992 the U.S. Department of Defense Legacy Resource Management Program provided initial funding to restore approximately 3,000 acres of Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.) ecosystem. Prior to Air Force ownership, the forest had been clearcut during a twenty-year period and left in a severely altered condition. The U.S. Air Force formed a collaborative partnership with the Alligator River National Wildlife Refuge, North Carolina Division of Forest Resources, and North Carolina State University. Representatives from these agencies organized a steering committee and developed a strategic plan to accomplish the following: inventory cutover and remnant forest stands, promote and enhance natural regeneration, develop seed and seedling sources, develop and implement artificial regeneration methods, restore previously high-graded stands, implement a geographic information system and differential global positioning system, and establish water control and management to restore a more natural hydrologic regime.

INTRODUCTION

Dare County Air Force Range was established in northeastern North Carolina in 1964. The Range is situated on a peninsula bordered by the Alligator River, Pamlico Sound, and Croatan Sound. It provides bombing and gunnery training for fighter pilots in the U.S. Air Force, Navy, Marine Corps, and Air National Guard. Ordinance delivery and strafing are restricted to two impact areas; each area is approximately 2,500 acres in size.

The balance of 42,000 acres is managed under ecosystem management principles in conjunction with multiple-use and sustained yield policies. These buffer lands are made up of swamp forests, pocosins, and freshwater and saltwater marshes. The Range is completely surrounded by the Alligator River National Wildlife Refuge which is administered by the U.S. Fish and Wildlife Service. Featured plant communities include Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.) and old-growth pond pine (Pinus serotina) forests. Protected animal species include the red cockaded woodpecker, red wolf, American alligator, and black bear.

The Dare County peninsula has a long history of timber management. Dare Lumber Company harvested Atlantic white-cedar from 1885 until 1930. West Virginia Pulp and Paper Company managed their forest resources from 1950 to 1975, during which time extensive road and canal systems were established. Mac Millan Bloedell Inc. harvested Atlantic white-cedar from 1975 to 1985. Alligator Timber Company continued harvesting Atlantic white-cedar from 1985 to 1989.

The Air Force purchased all available timber rights on Dare County Range in 1981 which included extensive tracts of Atlantic white-cedar forest in cutover condition. The Air Force started a natural resources management program at the Range in 1985.

In 1992 the Department of Defense Legacy Resource Management Program provided the only means available to initiate restoration of the severely altered Atlantic white-cedar ecosystem. Genetic and species preservation, enhanced biological diversity, wetland restoration, and increased aesthetic considerations are far-reaching benefits to be gained from this project. Thus far, the Legacy program has provided more than one million dollars for this effort. The Air Force Air Combat Command provided additional funding from the Conservation and Forestry programs. The U.S. Fish and Wildlife Service and the North Carolina Division of Forest Resources have also contributed substantial funds and expertise towards this project.

The U.S. Air Force formed a collaborative partnership with the Alligator River National Wildlife Refuge, North Carolina Division of Forest Resources, and North Carolina State University. Representatives from these agencies formed a steering committee chaired by the Dare County Range forester, and adopted a strategic plan. A basic premise of the committee was to fund only those activities that would result in Atlantic white-cedar establishment and production. Elements of the strategic plan include:

1. Research the local area's silvicultural history
2. Review available literature on Atlantic white-cedar
3. Inventory cutover areas for natural regeneration
4. Inventory remnant Atlantic white-cedar stands
5. Promote and enhance natural regeneration
6. Develop seed and seedling sources
7. Develop and implement artificial regeneration methods
8. Restore previously high-graded stands
9. Implement a geographic information system
10. Establish a differential global positioning system
11. Establish water control and management to restore hydrology
12. Repair roads for access

Interagency partnerships are dynamic by nature. They require formulating common goals and long-range planning to address inherent differences in policy, procedures, and work loads. In the case of Atlantic white-cedar restoration, regularly scheduled meetings have been effective in addressing issues related to contractual procedures, administrative charges, funding procedures, and fiscal schedules between federal and state governments. A continual, open dialogue has helped to avoid problems and formulate solutions.

An initial objective was to contract an inventory of the nearly contiguous 3,000 acres of cutover tracts to determine success or failure of natural regeneration and the level of competing undesirable plant species. The project area is shared by the Dare County Range and Alligator

River National Wildlife Refuge and is almost equally divided by their common boundary. Bids received from prospective contractors ranged from 100,000 to 2 million dollars. After reviewing the proposals, the steering committee decided to use Refuge personnel and temporary hires to accomplish the inventory. In addition a forestry consultant firm was contracted to inventory 1,400 acres of remnant mature Atlantic white-cedar stands on the Range. Refuge staff will inventory remnant stands on Alligator River National Wildlife Refuge.

In a preliminary experiment, areas with a sufficient number of Atlantic white-cedar seedlings (600 stems per acre and greater) were treated with herbicide to release the seedlings from overtopping vegetation. Wax myrtle and gallberry shrubs were the most difficult of the competing plant species to control because of the waxy cuticle covering their leaves. The herbicide Arsenal proved to be the most effective on these plants. Working with representatives from American Cyanamid, Dare County Range was one of three test sites in an effort to add release of Atlantic white-cedar to the Arsenal label. The success of the test at the Range led the Environmental Protection Agency to approve the new label in August of 1995.

Legacy funding was also provided to Mr. Lenwood Smith, a graduate student from North Carolina State University, to investigate the interrelationships and effects of soil type, time of year harvest, and subsequent site conditions on natural regeneration of Atlantic white-cedar. Mr. Smith's thesis was completed in 1995 and concluded that overall, regeneration was found to be more probable on Belhaven and Pungo muck soil types logged in the winter. Soil acidity and percent base saturation were also found to be good indicators of Atlantic white-cedar trees or saplings in both soil types. Hydrology appeared to be more critical to Atlantic white-cedar success on Pungo muck soils where different sediment deposits are found beneath the organic layer than on Belhaven soil. General observations indicated that the presence of Sphagnum moss could be linked to the success of Atlantic white-cedar and microrelief also appears to play an important role in Atlantic white-cedar success.

Innovative logging methods are being tested in an effort to minimize soil disturbance during harvest operations. Approximately 70 acres of mature (60 years old or older) Atlantic white-cedar has been successfully, naturally regenerated using clearcut harvesting. A seed-tree regeneration harvest of 20 acres is planned for 1997. One harvesting method involves placing the harvester on mats and installing dual wheels with large rubber tires on front and back axles of conventional rubber-tire skidders. An extraction method effective in reducing soil disturbance and rutting involves constructing corduroy skid trails from timber and logging slash. However, some rutting is desirable; it provides microtopography that enhances seed germination and establishment. Merchantable timber from the corduroy skid trails is extracted upon completion of the harvest operation.

In the beginning, the most limiting factor we faced in our efforts to restore previously high-graded timber stands was the lack of available seedlings. Production of Atlantic white-cedar seedlings was last attempted by West Virginia Pulp and Paper Company in the mid-to-late 1950s. Weyerhaeuser Corporation successfully initiated the propagation of containerized rooted cuttings.

The North Carolina Division of Forest Resources began producing seedlings from seed in 1994, but not in large quantities due to the limited seed supply. Thus far, 90 acres have been hand planted with survival rates above 95 percent.

The Legacy project funded several U.S. Forest Service projects in 1993. The experiments were conducted at the Southern Forest Experiment Station. Improved techniques were developed for extracting, cleaning, germinating, testing, and storing seeds. Soil seed bank tests indicate that Atlantic white-cedar seed is viable for at least three years. Preliminary results from a tetrazolium test indicate that trees with adequate cross pollination can yield viable seed at six years of age.

The Legacy project also funded several North Carolina Division of Forest Resources research projects. In 1993 the North Carolina Division of Forest Resources established a provenance study plot at Dare County Range. This study will determine genetic variation of growth, wood structure, and aromatic oil content of trees within local seed sources and between different soil types across the coastal plain of North Carolina. Seedlings were grown from seed extracted from five high quality trees which exhibited superior growth characteristics on the Range. The containerized seedlings were planted in peat soil. Other soil types included in the concurrent studies are wet mineral and stream floodplain. A solar powered electric fence was required to protect the young seedlings from deer browsing for the first four years. Seedlings also experienced browsing by rabbits. On the contrary, little to no browsing was observed in the naturally seeded or hand planted tracts.

The North Carolina Division of Forest Resources is conducting two studies related to nursery production of Atlantic white-cedar. One involves monitoring the effects of soil temperature and sunlight intensity to determine the best cultural practice and soil treatment to enhance seed germination and subsequent growth for bare-root seedling production. The other is a seedling standard evaluation study which will provide information to help guide decisions made by the nursery staff on what is considered to be an acceptable bare root-seedling for distribution.

Several methods of site preparation in organic soils are being evaluated. These include mowing, roller drum chopping, sheering and piling, herbicide applications, and a combination of herbicide and burning. Mowing was determined to be too costly. Physical limitations associated with heavy equipment pulling a roller drum chopper over saturated organic muck soil proved to be too difficult to overcome. The other four methods will be attempted in future years.

A hydrology study scheduled to begin in 1998 is designed to restore a more natural hydrologic regime to the 3,000 acres of wetlands that were altered by past logging practices. The network of roads and canals constructed to access timber resources function like dams. They impede sheet flow and impound water, resulting in water stagnation and conversion of forested wetland habitat. This project will result in improved water circulation, hydrologic regimes, and water quality, thereby improving the growing conditions for Atlantic white-cedar forests.

The Range and Refuge staffs are working together to develop a geographic information system using MapInfo software. A global positioning system base station has been established to provide accurate maps using differential correction software. This element has augmented partnership opportunities through sharing digital databases, equipment, expertise, and volunteer services.

Final analysis shows that the Department of Defense Legacy Resource Management Program project is a public relations success for the Air Force and all partners involved. New information is being discovered that will lead to the recovery and management of the Atlantic white-cedar forest ecosystem.

INVENTORY OF REMNANT ATLANTIC WHITE-CEDAR STANDS IN NORTH CAROLINA

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Abstract--A state-wide inventory of remnant Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.) stands was conducted during 1996 and 1997. All known pure and mixed stands greater than four acres were cataloged; numerous sites were included that contained smaller stands and groves. Ground accessible sites were visited, and stand data were collected, including size, age, species composition, diameter at breast height, height, and basal area. Inaccessible sites, mainly in northeastern counties, were aerially inspected. Soil type, ownership, and natural community type were recorded for all sites. Stands were located based on information provided by the NC Natural Heritage Program, The Nature Conservancy of NC, NC Department of Agriculture, botanist Cecil Frost, NC Department of Forest Resources Staff Forester K.O. Summerville, NC Department of Forest Resources County Rangers, Weyerhaeuser Senior Forest Scientist Joe Hughes, public land managers, and others, as well as county-by-county observations.

Nearly 200 sites were inspected on which Atlantic white-cedar presence was confirmed. Sites were located in 27 counties in the coastal plain and piedmont. Counties with the greatest number of total sites included Dare, Tyrrell, Hyde, Washington, Hoke, and Brunswick. Counties with the largest site sizes included Dare, Tyrrell, Hyde, Washington, and Camden. Counties with relatively high numbers of small acreage sites included Hoke, Cumberland, and Sampson. Other counties with remnant stands or groves included Bladen, Lee, Harnett, Wilson, Nash, Richmond, Currituck, Hertford, Gates, Pasquotank, Beaufort, Craven, Wayne, Jones, Onslow, New Hanover, Fender, Pamlico, and Columbus.

PRODUCTION AND QUALITY OF ATLANTIC WHITE-CEDAR SEED IN COASTAL NORTH CAROLINA

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Abstract--A 3-year study of Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.) seed production and quality in North Carolina revealed that: (1) drying cones at 35 or 40(C combined with 1 or 2 wet/re-dry cycles extracted 90% or more of the viable seeds without damage; (2) on the average there were about 10 seeds per cone, with only 1 or 2 of those filled; (3) seed lots may be cleaned to a high degree of purity and fullness with air-screen cleaners and small seed blowers, although some filled seeds must be sacrificed to achieve the latter; (4) stratification for 4 weeks produced near-maximum germination at the fastest rates for most seed lots, although geographic and seed-year variations still occurred; (5) yields and germination of seeds from trees less than 10 years of age were equal to that of seeds from older trees (45+ years); (6) natural seedfall in two well-stocked stands placed some 800 to 1,500 viable seeds per m2 in the top 5 cm of the litter, and buried seed tests showed that as many as half of these could survive for 1 year in the litter, and some for 2 years.

INTRODUCTION

Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.) is a valuable tree of coastal wetlands that occurs in a narrow belt from southern Maine to southern Mississippi (Little 1979). Its wood is highly prized for boats, posts, and utility poles (Kuser and Zimmerman 1995). An intermediate tolerance to shade and rather exacting seedbed moisture requirements (Little and Garrett 1990) combine to make natural regeneration of Atlantic white-cedar problematic on many sites. The recent widespread interest in preserving and restoring forested wetland ecosystems has brought increased attention to artificial regeneration of this species and to a number of the problems associated with seedling production.

Seed production by Atlantic white-cedar is prolific, but as for many such species, there seems to be a large proportion of the seeds that are empty. Because seed production begins at the early ages of 3 to 5 years (Little and Garrett 1990), and cone collection from young trees is very easy, questions are frequently raised about the quality of seeds from very young trees. Varying degrees of dormancy also contribute to the difficulties of seedling production (Boyle and Kuser 1994). A desire for better stand establishment of Atlantic white-cedar on the Alligator River National Wildlife Refuge, North Carolina, (ARNWR) by the U.S.Department of the Interior Fish and Wildlife Service, and the U.S. Department of Defense prompted the studies on seed production and quality described in this paper.

MATERIAL AND METHODS

General

The majority of seeds used in these studies were collected by personnel of the U.S. Fish and Wildlife Service, U.S. Air Force, and North Carolina Division of Forest Resources on or near the ARNWR from 1992 to 1994. Cones were partially dried, bagged, and shipped to the U.S. Forest Service Seed Research Laboratory in Starkville, Mississippi, for seed extraction and testing. Upon receipt, the bags were opened for additional drying. No evidence of damage to cones or seeds during shipment was observed. Some samples were extracted in North Carolina, and the seeds were shipped to Starkville. Cone collections in Jackson County, Mississippi, were made by the senior author.

For evaluation of the soil seed bank potential, blocks of litter/soil were collected on the ARNWR and sent immediately to Starkville. For tests of seed longevity in the soil, samples of cleaned seeds were placed in mesh bags in Starkville and flown to the Refuge for burial on forest sites. Bags were retrieved each year and shipped to Starkville for analysis of the quality of the remaining seeds.

Extraction and yield

Cones collected in 1992 from mature trees (45+ years) at two Dare County, NC, stands: Milltail Creek (within the ARNWR) and Sycamore Road (within the U.S. Air Force Dare County Range). Cones were dried in petri dishes for 24 hours at temperatures of 30, 35, or 40(C ((1() maintained in forced-draft laboratory ovens. The cones were then uniformly shaken by hand in a box for 1 minute to extract the seeds. In one treatment group, the cones were then dissected by hand to recover all seeds. Other cone samples were subjected to wet/re-dry cycles. They were sprayed with a water mist and enclosed in plastic bags for 10 to 12 hours to ensure cone closure, re-dried at the same temperatures, and re-shaken. There were four treatments: 0, 1, 2, and 4 wet/re-dry cycles. After the last shaking, each cone was dissected by hand to recover all seeds. There were 4 replications of 25 cones each for each temperature and wet/re-dry cycle combination. Extraction efficiency was calculated by dividing number of seeds shaken from the cones by total number of seeds in the cones (shaken + hand-extracted).

Another test was carried out with 1993 cones from mature trees from both stands. All drying was on a table in the laboratory (23(C, 50% RH), and all cones went through 3 wet/re-dry cycles. It took about 5 days for cones to open completely under these conditions. Each seed fraction was weighed and x-rayed to determine the number of filled seeds. Samples of these seeds were cleaned and upgraded (empty seeds removed) with a seed blower, then germinated without any pretreatment in cabinet germinators under official test conditions (ISTA 1993). The seeds were placed on moist germination blotters under an alternating temperature regime of 8 hours (light) at 30(C, then 16 hours (dark) at 20(C.

Individual tree collections were also made in 1992 from 60 trees in young plantations and natural stands, ages 8 to 10 years, from 15 counties in North Carolina. Four bags of 100 cones each were collected from each tree. These cones were dried indoors, shaken to remove seeds, then crushed to ensure that all seeds were removed. After cleaning, the seeds were x-rayed to determine how many seeds were filled, then germinated as described above. Average yields per cone were calculated from the bulked lots, and not from individual cone data.

Seed cleaning

Different methods for cleaning and upgrading (removing empty seeds) were tested on the bulk collections of several years and various stands. No planned experiments were carried out; methods were worked out by trial and error.

Stratification trials

Several stratification trials were carried out to assess the degree of dormancy encountered in different seed lots. Samples of 50 or 100 seeds were imbibed overnight in polyethylene bags of tap water at room temperature. The excess water was poured off, and the bags were placed in a refrigerator at 2-3(C for periods ranging from 2 to 12 weeks. Seeds were then germinated as described previously, except that test periods were sometimes extended to make sure that all viable seeds germinated. Light requirement for germination was tested with a paired test of light and dark germination with foil-covered petri dishes in the same germinators.

Soil seed bank

Soil and litter blocks 10 x 10 x 5 cm (4 x 4 x 2 in) were removed from the surface in two stands in the ARNWR. These blocks were carefully cut into 3 layers approximately 2.5 cm (1 in) thick and placed in germinators set at the conditions described previously. When germination was apparently complete, the blocks were removed, dried, crushed, and sifted through a screen mesh to recover the remaining seeds. These seeds were examined and classified as "good" or "bad". "Good" seeds were full-sized and apparently fully developed; "bad" seeds were undersized or broken.

Longevity was tested by burying plastic mesh pouches with 100 seeds each at 12 plots in each of two stands: Sycamore Road in 1993 and Milltail Creek in 1994. The pouches were covered with about 1 in of litter. One pouch was retrieved from each plot annually, and the surviving seeds were counted and germinated in the Starkville laboratory as described previously.

RESULTS AND DISCUSSION

Extraction and yield

Extraction efficiency exceeded 90% at all temperatures when used in combination with wet/re-dry cycles (Table 1). Drying at 30(C required 3 cycles to achieve this level; 35(C required 2 cycles; and 40(C required only 1 cycle. Results were similar for both collections. This technique is used on other conifer species and is sometimes referred to as "teasing" the seeds from the cones. In extraction of the 1993 bulk collection from Milltail Creek, each cycle yielded fewer seeds and slightly lower proportions of filled seeds (Table 2). When samples from the fractions were tested, however, fraction #1 germinated 55.0%, and a bulked sample from fractions #2 and 3 germinated 62.8%. Fewer filled seeds were recovered in repeated wet/re-dry cycles, but their quality equaled that of seeds recovered in the first drying.

Average total seed yields per cone from mature trees in 1992 were 9.4 (0.4 for the Sycamore Road lot and 7.6 (0.3 for the Milltail Creek lot. Average number of filled seeds, however, was only 1.0 for the Sycamore Road lot and 0.6 for the Milltail Creek lot. Yields from the young trees in 1992 were similar. They averaged from 2.1 to 10.2 total seeds per cone and <0. 1 to 1.4 filed seeds per cone. Yields from mature trees in 1993 from Milltail Creek and Sycamore Road averaged 4.9 and 2.5 seeds per cone and 2.0 and 0.3 filled seeds per cone. Collections from young trees in 1993 from many of the same areas used in 1992 produced comparable counts: 5.2 to 8.6 total seeds per cone and 0.2 to 1.7 filled seeds per cone. These results confirm the widely-held belief that there are typically very few filled seeds in Atlantic white-cedar cones. Bianchetti and others (1993) report approximately 20% filled seeds in a bulked sample of North Carolina sources. Yield differences among locations and stands are likely due to variation in pollen supply or weather during pollination. The results also clearly show that there were no differences between mature and very young trees in yield and quality of seeds.

Seed cleaning

Preliminary cleaning of seed lots was successfully carried out with small air-screen cleaners or hand screens of the same type. Cones and large debris were removed with a #10 1/2 (4.2 mm) round-hole screen, and smaller debris, primarily needle fragments, was removed with a #7 (2.8 mm) round-hole screen. Two or three passes over the #7 screen were required to remove most of the small debris. Other screen sizes may be required for other collections, as seed size can vary among sources and years.

Very fine debris and a significant amount of empty seeds were removed from the small lots with the Stults, and General ER(r) laboratory blowers. For larger lots, the same thing could probably be accomplished with a fractionating aspirator, but we were unable to test such a machine in this study because of the small lot sizes. With the 1992 collections, cleaning and upgrading as described above produced final purities of 81 and 94% for the Sycamore Road and Milltail Creek lots respectively. Average seed weights were 1,136 ░ 18 and 1,1421 ░ 19 seeds per gram for these lots. To reach purities of this level, however, seed managers must be prepared to lose some filled seeds in the process. We upgraded one lot from Croatan National Forest in North Carolina to 60% filled seeds, and higher levels are possible. The amount of losses will vary by seed lot, but the cost seems small to pay for lots of high purity and fullness.

Stratification trials

The first stratification test compared periods of 0, 4, 8, and 12 weeks with an older seed lot stored by the North Carolina Division of Forest Resources. These seeds were apparently quite weak, as it took 140 days to get complete germination (Table 3). The results suggest that stratification certainly stimulated germination, but that even 12 weeks might not be enough for maximum germination. The second test, with seeds from the bulk collections in 1992 from Milltail Creek and Sycamore Road stands compared only 0, 2, and 4 weeks. It confirmed the benefits of stratification, but 4 weeks did not appear to be long enough, even though the test was allowed to run for 48 days (Table 3). Light slightly increased germination of unstratified seeds of these lots: 9% for Milltail Creek and 3% for Sycamore Road. A third test with 1992 bulk collections from Brunswick and Jones Counties, North Carolina, suggested that 4 weeks was optimum in terms of germination rate and also for total germination for one of the lots (Table 4). In the fourth stratification test, there were 12 seed lots, 11 from eastern North Carolina, and 1 from Jackson County, Mississippi. The combined results (Table 5) show germination rate only, expressed both as mean germination time (MGT) and peak value (PV) after Czabator's (1962) method. Germination rate was definitely greater with 4 weeks of stratification. Some of these lots were from very young trees (< 10 years) in natural stands, and their performance was equal to that of seeds from mature trees.

Bianchetti and others (1993) reported that 14 days of stratification was enough to produce maximum germination in 28 days in the laboratory, but they did not report any germination rate data. In nursery production, however, rate of emergence is often the key to success, and the treatment that gives the greatest rate of germination should be favored in seedling production systems. Atlantic white-cedar is notorious for variable dormancy, so 4 weeks may not be the optimum period for all seed lots. In our last test with 12 different lots, 4 weeks was not the optimum for all of them, but it was for most. Boyle and Kuser (1994) found that 30 days of stratification was enough for seeds from eight swamp sites in New Jersey. Four weeks appears to be a good general recommendation for the species unless preliminary tests show a different optimum for particular geographic sources or years.

Soil seed bank

It was difficult to separate the layers without some mixing occurring, but there were viable seeds in each layer. Total viable seeds (all depths) were 585 per m2 for the Sycamore Road stand and 325 per m2 for the Milltail Creek stand. The ungerminated seeds were too numerous to cut, but if only 10% of them were viable (based on the earlier tests), there were another 1,000 viable seeds per m2 at the Sycamore Road stand and 500 per m2 at the Milltail Creek stand. Fowells (1965) reports that from 64 to 2,718 viable seeds per m2 were found in the surface inch of litter in New Jersey stands of Atlantic white-cedar. These data suggest that there were plenty of viable seeds present in the litter in these stands for natural regeneration to occur when the overstory is removed. About half of the seeds buried in pouches survived the first year, and some survived the second year (Table 6). Although the loss of 50% of the viable seeds after one year seems serious, the large numbers found present would seem to be enough to produce some natural regeneration as long as two years after seedfall. In fact, field observations in New Jersey have suggested that seeds can remain viable in sphagnum moss on the forest floor for as long as 14 years (Kuser and Zimmerman 1995).

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Table 1--Extraction efficiencies for various cone-opening treatments on 1992 cones from mature trees at Milltail Creek, Alligator River National Wildlife Refuge, North Carolina. Results from the nearby Sycamore Road stand (not shown) were similar

Wet/re-dry	Extraction	
Temperature (C)	cycles (no.)	efficiency (%)
30	0	53
30	1	75
30	2	93
30	4	96
35	0	69
35	1	81
35	2	97
35	4	100
40	0	76
40	1	93
40	2	100
40	4	100

Table 2--Seed yield from bulk collections in 1993 from mature trees at Milltail Creek, Alligator River National Wildlife Refuge, North Carolina

Wet/re-dry cycles	Weight (g)	Percent of total	Filled seeds (%)
1	119.2	67	51
2	33.9	19	38
3	24.3	14	32
Totals	177.4	100	

Table 3--Results of stratification tests on old stored seeds from the NC Division of Forest Resources and the 1992 bulk collections from Milltail Creek and Sycamore Road stands in Dare County, NC. Percentages are based on total seeds. Test periods were NC Division of Forest Resources = 240 days, and 1992 Alligator River National Wildlife Refuge bulk lots = 48 days

Stratification period (weeks)	--Germination (%) and Source-- NC Div. For.	Milltail Creek	Sycamore Rd.
0	3.0	5.70	9.7
2	--	11.3	11.0
4	34.6	17.0	19.3
8	25.6	--	--
12	46.6	--	--

Table 4--Results of stratification tests on 1992 bulk lots from Brunswick and Jones Counties, North Carolina. The seed lots were extensively cleaned, and percentages are based on filled seeds only. Test period was 28 days

Stratification period (weeks)	Brunswick Co.		Jones Co.	
	Germ. (%)	Peak value (%/day)	Germ. (%)	Peak Value (%/day)
0	67.4	3.4	75.4	3.5
2	77.1	3.3	75.0	3.6
4	94.3	5.6	77.6	4.4
8	96.7	4.8	64.4	3.6

Table 5--Germination rate expressed as mean germination time (MGT) and peak value for four different stratification periods. Data represent mean values from 12 different seed sources collected in 1992, 1993, and 1994

Stratification period (weeks)	MGT (days)	Peak Value (%/day)
0	14.24	3.8
2	13.22	4.5
4	12.36	5.5
8	13.29	5.3

Table 6--Germination of seeds buried in litter at two sites in Dare County, North Carolina. Values are means of 12 plots. (ARNWR = Alligator River National Wildlife Refuge & AF= Air Force Range)

Original Site	% Germination after % germination	1 year	2 year
Sycamore Rd (AF)	17.0	7.1	6.6
Milltail Creek (ARNWR)	59.0	30.8	--

LINKING ECOSYSTEM MANAGEMENT, REFUGE MANAGEMENT AND ATLANTIC WHITE-CEDAR RESTORATION

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Abstract--Several years ago the U.S. Fish and Wildlife Service (USFWS) embarked on an ecosystem-based approach to management. Over 50 ecosystems were identified by the USFWS. The USFWS manages a National Wildlife Refuge System (NWRS), which is embedded in the landscape of these ecosystems. The NWRS has grown to over 92 million acres. There are over 500 refuges across the United States and its territories. Three refuges in northeastern North Carolina and southeastern Virginia that are in one of the designated ecosystems have significant remnant populations of Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.). The ecosystem approach to management, the goals of the NWRS, and the purposes for which these three refuges were created all speak to the need for management of Atlantic white-cedar stands, which historically formed a major component of the mid-Atlantic forested wetland system. The ecosystem approach to management recognizes the need for broad-based partnerships when trying to accomplish landscape-based biotic community restoration. Atlantic white-cedar restoration fits this description and the successes thus far are a result of effective partnerships.

INTRODUCTION

The USFWS began an ecosystem approach to management in 1994. To facilitate this management approach, the USFWS identified more than 50 ecosystems. This approach to management encourages us to manage for the benefit of the ecosystem even when our responsibilities are for the management of a specific land-base such as a national wildlife refuge.

ECOSYSTEM APPROACH TO MANAGEMENT

In at least one of these ecosystems, the Atlantic white-cedar (Chamaecyparis thyoides (L.) B.S.P.) wetland community was historically a significant component of the forested wetland system. This ecosystem is referred to as the Roanoke-Tar-Neuse-Cape Fear (RTNCF) ecosystem, and consists of the watersheds of the four named rivers and covers parts of southeastern Virginia and eastern North Carolina. There are three refuges in the RTNCF ecosystem having significant remnant populations of Atlantic white-cedar. These are Pocosin Lakes National Wildlife Refuge, Great Dismal Swamp National Wildlife Refuge, and Alligator River National Wildlife Refuge. Within the previous two decades and during implementation of the ecosystem policy, the USFWS established and managed these refuges. These refuges were established, in part, to conserve and manage their unique wetlands, including Atlantic white-cedar wetland forests.

The RTNCF Ecosystem Plan (1994) states as its vision the management of biodiversity by restoring, conserving, and improving the quality and quantity of functioning terrestrial and aquatic ecosystems for the benefit of native species in the wild. The plan emphasizes the need for partnerships to meet its nine goals and numerous objectives. One goal is the restoration and maintenance of viable levels of natural diversity across the landscape, with emphasis on a number of plant community types including Atlantic white-cedar.

NATIONAL WILDLIFE REFUGE SYSTEM

The NWRS began in 1903 and has evolved and grown to over 92 million acres in size. It now includes over 500 refuges, one in every state, and over 3,000 Waterfowl Production Areas. The original mission was clear -- preserve wildlife and habitat for people today and for generations to come. In 1996, Presidential Executive Order 12996 reemphasized that the NWRS's mission was to preserve a national network of lands and waters for the conservation and management of fish, wildlife, and plant resources of the United States for the benefit of present and future generations. At that time, the USFWS produced a "Promises" document stating its responsibility to protect, restore, and manage wildlife and habitat and to provide compatible, wildlife-dependant recreational opportunities for the public. Challenges identified in the "Promises" document include declining habitat and insufficient resources. The document stressed meeting the challenges and fulfilling our promises by strengthening existing partnerships and forging new ones.

Atlantic white-cedar is an important plant resource, providing habitat for wildlife. To meet the goals of the NWRS we must attempt to restore this wetland forest community. Successful restoration and conservation of Atlantic white-cedar will help provide quantity and quality of habitat that supports America's diverse wildlife heritage. Restoration efforts will employ an ecosystem approach to resource conservation that considers landscapes beyond refuge boundaries. Also, this project will serve as a demonstration area for private land conservation and as a model for sound land use and ethics.

ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE

Alligator River National Wildlife Refuge (ARNWR) was established in 1984 under the authority of two Federal laws: the Fish and Wildlife Act of 1956 and the Refuge Recreation Act, amended 1972. A synopsis of the refuge purposes follows: "for the development, advancement, management, conservation, and protection of fish and wildlife resources" and "suitable for ... the protection of natural resources, [and] the conservation of endangered species or threatened species."

A master plan was developed for ARNWR and revised in 1994. The plan states that the primary objectives of the refuge are to manage and protect the area's unique wetland habitats and associated wildlife species. Management efforts will be directed at restoring water levels that existed prior to alteration of this habitat. Past and present management have reaffirmed that one of the primary objectives for this refuge is wetland restoration. This restoration includes the re-establishment of former hydrologic regimes and forest communities.

ARNWR has at least 8,000 acres of clearcuts. Many of these clearcut acres contained Atlantic white-cedar stands. The Atlantic white-cedar biotic community has been identified as critically endangered. The RTNCF ecosystem, the NWRS, and the ARNWR plans have as their goals the restoration, management, and conservation of the Atlantic white-cedar community. It was recognized early on that the refuge did not have the resources to accomplish Atlantic white-cedar restoration by itself. Partnerships would have to be developed.

ARNWR nearly surrounds the 46,000-acre U.S. Air Force Dare County Range. The habitat is contiguous and similar to that of the ARNWR. The ARNWR formed partnerships with the U.S. Air Force, U.S. Forest Service Seed Lab at Mississippi State University, the NC Division of Forest Resource Nursery, and NC State University Forestry Department in an effort to determine the best methods for Atlantic white-cedar restoration. Most of the work was funded through the Department of Defense Legacy Resource Management Program. The work has inventoried cutover tracts and remnant Atlantic white-cedar stands, established and utilized geographical information systems and global positioning systems, developed natural and artificial regeneration methods through applied research, improved management capabilities by improving roads and restoring additional wetlands, and increased public awareness of these efforts.

REASON AND NEED FOR LINKAGES

Many agencies interested in and tasked with restoring, managing, and conserving native biotic communities have limited resources. Successful forested wetland conservation requires a landscape-based management approach. Thus, Atlantic white-cedar restoration goals can only be achieved through joint efforts. The USFWS, along with all of its partners, has recognized this. The current Atlantic white-cedar conservation effort is a model for success and is necessary to achieve our goal of Atlantic white-cedar restoration in its historic range.